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RICE CULTIVATION IN INDO-GANGETIC PLAIN AS INFLUENCED BY METHODS OF ESTABLISHMENT – A REVIEW

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ABSTRACT

Manual transplanting into puddled soil is a traditional method of rice cultivation. With the increasing scarcity of water, labor and energy this method of rice cultivation becomes less profitable and sustainable. So, there is a need to find alternative rice establishment methods to the traditional practice of manual transplanting in puddled soil. In rice, planting methods have an impact on the growth, yield attributes, yield, maturity, quality parameters besides physical conditions of soil, water requirement and cost of cultivation and labour requirement. Direct seeded rice showed better initial establishment and gave comparable yield to transplant rice. Direct seeded rice takes less time to maturity and gave higher water productivity, net return and benefit: cost ratio than transplanted rice.

KEYWORDS: Rice, Establishment Methods, Manual Transplanting & Direct Seeded Rice

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INTRODUCTION

Rice is traditionally grown by the transplanting of seedlings, which involves replanting of rice seedlings grown in nurseries in puddled soils. The sustainability of this system is threatened due to increasing scarcity of resources, especially water, labor and energy. Now, it is the demand of time to shift from puddled transplanted rice establishment method to other sustainable method of establishment such as direct seeded rice.

Growth and Development

Growth and development of the rice plant involve continuous change. This means important growth events occur in the rice plant at all times. Therefore, the overall daily health of the rice plant is important. Method of establishment is one of the cultural practices, which influences the rice crop through its effect on growth and development (Gopi *et al*. 2006). He and Kim (1997) observed higher crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf area index (LAI) in direct sown crop than in a mechanically transplanted crop from tillering to heading stages (Figure 1). They also stated that chlorophyll content and root activity were higher 15 days after heading in direct sown rice. Gill *et al.* (2006) observed that direct seeded rice produced more leaf – area index, effective tillers and dry matter accumulation than transplanted rice (Table 1). Chinnusamy *et al.* (2009) observed that row sown rice showed rapid establishment and greater vegetative growth due to absence of transplanting shock. Tiller number per unit area and leaf area index were also more in row sown rice than in broadcasted and transplanted rice. Gill and Walia, (2013) reported that direct-seeded basmati rice with brown manuring recorded significantly higher dry matter accumulation, LAI and effective tillers m^{-2} than transplanted basmati rice.

Yield Attributes

Yield attributes are important determinants of grain yield and accounts for major variations in rice grain yield. Singh and Pillai (1996) concluded that direct seeded rice gave a similar grain yield of transplanted rice due to statistically similar values ancillary characters (Table 2). Similarly, Miyagawa *et al.* (1998) reported that the yield of direct sown rice and transplanted rice did not differ significantly in irrigated conditions due to profuse vegetative growth and a large number of spikelets panicle^{-1}. Gill *et al.* (2006) observed that significantly more effective tillers m^{-2} and grain yield was obtained in direct seeded rice over transplanted rice, but panicle length and test weight were statistically similar under both methods of establishment. Sharma *et al.* (2005) concluded that yield attributes effective tillers m^{-2} and panicle length and grain yield did not differ significantly under both methods of establishment viz., Direct seeding and transplanting. Bhushan, et *al.* (2007) recorded that rice yields were similar under direct drill-seeded after no tillage and conventionally transplanted methods due to similar values of yield components. Gill and Walia (2013) reported that direct-seeded basmati rice with brown manuring produce significantly higher effective tillers m^{2}, spikelets panicle^{-1} and grains panicle^{-1} than transplanted basmati rice (Table 2).

Yield

Grain yield is a function of various growth and yield attributing parameters. Grain yield is the main criterion for judging the comparative efficacy of different methods of establishing. Singh and Singh (1993) found that the direct seeded rice in lines gave a significantly higher grain yield (26.80 q ha^{-1}) than transplanted rice (25.50 q ha^{-1}) which was 4.30 per cent more over transplanting method. Narayansamy *et al.* (1993) reported that dry seeding of rice by drilling in lines (52.6 q ha^{-1}) recorded similar grain yield of transplanted rice (55.6 q ha^{-1}). Singh and Pillai (1996) also reported that direct seeded and transplanted rice gave a similar grain yield (Table 3). Sharma *et al.* (2005) reported that direct seeding under unpuddled conditions and transplanting methods of rice establishment gave a similar yield owing to almost equal crop stand under direct seeding and transplanted conditions (Table 3). Gill *et al.* (2006) revealed that maximum rice grain yield (48.30 q ha^{-1}) was recorded in direct seeding which was significantly more than the transplanting (43.80 q ha^{-1}) with a margin of 5.50 q ha^{-1}. Gill (2008) Reported that direct seeded rice recorded 2.5 q ha^{-1} more grain yield (68.2 q ha^{-1}) than transplanted rice (65.7 q ha^{-1}). Bhushan, et *al.* (2007) reported that rice yields were equal under conventional transplanting and direct drill seeding after no-tillage methods (Table 3). This indicated that the puddling of soil, for which normally a large amount of water and labor are required, can be avoided without any yield penalty in rice. Gangwar *et al.* (2008) reported that direct seeded hybrid rice yield (82.0 q ha^{-1}) was significantly more than the manually transplanted rice (76.5 q ha^{-1}). Gangwar *et al.* (2009) reported that the yield of rice with direct seeding method and manual transplanting method was statistically similar (Table 3).

Maturity

Saikia *et al.* (1992) observed that direct seeded crop mature 15 days earlier than transplanted one which is an advantage in intensive cropping system. Alexander and Martin (1995) reported that the establishment of roots from the start of germination and also the availability of sufficient moisture from the date of sowing favored earlier flowering in direct seeding (wet seeded rice) (Table 4). Transplanting shock in transplanted rice resulted in late flowering as compared to wet seeded rice that broadcasting of sprouted seeds and drum seeding methods had 7.2 and 6.9 days earlier flowering than transplanted crop. However, drum seeding gave numerically higher grain yield and similar trend was also followed in the case of straw yield. Budhar and Tamilselvan (2002) enumerated that the direct seeding by manual broadcasting and

drum seeder reduced the time in 50 percent flowering by 7 days compared with transplanting (average of two seasons) (Table 4). Gill *et al.* (2006) reported that the direct seeded crop tool, on an average, 120 days for maturity compared to the transplanted crop which took 130 days for maturity and showed an advantage of 10 days earlier maturity. Gill, (2008) reported that the direct seeded rice took 113 days to maturity, whereas transplanted rice matured in 125 days clearly showing that direct seeded rice crop did not experience any transplanted shock and as a result it matured 12 days earlier. Earlier maturity might have enabled the crop to fit best in different cropping systems (Table 4).

Growth Pattern of Roots

Growth of roots was faster from transplanting to panicle-initiation stage of rice. Root-dry weight increased by 3 times during the period between tillering and panicle-initiation stages. From panicle- initiation stage to flowering, the increase in root weight was found 2 times more, but in subsequent stages the root weight decreased mainly due to decay in old root mass with a little root mass addition (Reddy and Reddy 1992). Mandal *et al.* (2013) recorded that root mass density under traditional flooded rice was on an average 60% higher the aerobic rice and the cortex cells were disintegrated more in case of aerobic rice compared to transplanted flooded rice (Figure 2.). Sekhon *et al.* (1988) reported that rice root density was 498 µg cm^{-3} in soil kept near 60% field capacity and increase to 735 µg cm^{-3} in submerged soil (4-6 cm standing water). The amount of roots in upper 5cm of soil increased with decrease in redox potential.

Root Morphology

Root morphology was substantially altered by moisture regimes. With continuous submergence where the soil mechanical resistance was lowest, roots grew freely without any waviness. The roots were porous with more aerenchymatous tissues. The roots were highly branched and the number of tertiary roots was 6.2 cm^{-1}, whereas under a lower moisture regime of saturation to field capacity, they were 1.0 cm^{-1}. Yoshida (1981) reported that rice developed sixth-order roots under lowland conditions. The root diameter became successively smaller (ranging from 1,000 to 40 µm) as the order of branching increased. The average diameter of primary roots was 1 mm; whereas that of tertiary root was 0.25 mm. Root environment has a great effect on formation of root hairs. Root hair formation is favored by aerobic conditions in upland soils (Kawata and Ishihara 1959, Kawata and Ishihara1961, Kawata *et al.* 1964). Reductive conditions of flooded soils impair root hair formation. In soft upland soils maximum rooting depth of most rice varieties reaches 1 meter or deeper. Rice roots seldom exceed a maximum depth of about 40 cm in flooded soils with an impaired water percolation (anaerobic environment). Environment also controlled actual root depth in the field, along with genetic ability. Roots grew against gravity towards the soil surface under continuous submergence. The percentage of non-geotropic roots to total root weight was 11.8%, whereas it was 4.7 with a moisture regime of saturation field capacity. No such roots were observed with plants grown under upland condition. This growth of non-geotropic roots possibly is a mechanism for absorption of oxygen (Reddy and Reddy 1992).

Water Requirement of Rice

Narayansamy *et al.* (1993) also reported that the dry seeding by drilling consumed the least quantity of irrigation water and recorded higher water use efficiency as compared to transplanted rice (Table 5). Balasubramanian and Krishnarajan (2000) revealed that direct seeding of rice recorded higher water use efficiency than transplanted rice during *kharif* season (Table 5). Gill (2008) observed that the direct seeded rice gave more water productivity of irrigation water as compared to transplanted rice (Table 5). Gill *et al.* (2006) revealed that the water productivity of direct seeded rice was

higher against transplanted rice, thus showing superiority in productivity and saving in irrigation water under direct seeded rice (Table 5). Bhushan, et *al.* (2007) reported that puddled transplanting of rice treatment required 19.2 % more irrigation water than no-tillage direct seeded rice treatment. Water use efficiency was higher with no-tillage direct seeded rice (0.32 g L^{-1}) than with transplanted rice after puddling (0.21 g L^{-1}) (Table 5).

Physical Conditions

Sharma *et al.* (1995a) revealed that the water infiltration rate was significantly lower in transplanted rice 0.02 cm HR^{-1} than in direct seeded field 0.06 cm HR^{-1} in both the years. Bulk density in direct seeded rice at 0-10, 10-20, and 20-30 cm depth was 1.35-1.36, 1.42-1.44 and 1.47-1.47 Mg m^{-3} which was lower than transplanted rice with bulk density 1.35 – 1.39, 1.43-1.47 and 1.47-1.50 Mg m^{-3} at 0-10 cm, 10-20 and 20-30 cm depth in both years 1990-1991. Gupta *et al.* (1989) and Tripathi (1992) also showed similar results. Sharma *et al.* (1995b) observed that direct seeding of rice helped to maintain physical conditions of soil, which proved advantageous in attaining desired tilth and timely sowing of the succeeding crop. Gangwar *et al.* (2008) reported that infiltration rate was higher 1.32 cm HR^{-1} in more direct seeding (dry bed) than mechanical transplanting (puddled) 0.70 cm HR^{-1} and manual transplanting (puddled) 0.82 cm HR^{-1}. Bulk density was lower in direct seeding (dry bed) 1.46 Mg m^{-3} than mechanical transplanting (puddled) 1.49 Mg m^{-3} and manual transplanting (puddled) 1.48 Mg m^{-3}. This may be due to settling of soil particles, which increased the bulk density greatly under puddled condition (Gangwar *et al.* 2006). Gangwar *et al.* (2009) observed that changes in soil physical – chemical properties after 4 years indicated that the highest infiltration rate 1.32 cm HR^{-1} and low bulk density 1.46 Mg m^{-3} were recorded under direct seeding – dry bed, while organic carbon, total nitrogen, available phosphorus and potassium were increased by 4.08, 31.82, 7.59 and 30.5% over their initial content under mechanical transplanting – puddled. Gangwar and Singh (2010) revealed that highest infiltration rate 1.32 cm HR^{-1} and lowest bulk density 1.46 Mg m^{-3} were recorded under direct seeding dry bed, while organic carbon, total nitrogen, available phosphorus and potassium were increased by 4.08, 31.82, 7.59 and 30.5% over their initial content under mechanical transplanting – puddled.

Quality Parameters

Gill and Walia (2013) reported that direct seeding (drilling in dry, moist soil), machine transplanting and manual transplanting of basmati rice resulting in similar brown, milled and head rice recovery. Different establishment methods of basmati rice had no significant effect on cooking qualities of basmati rice (Figure 3 & 4). Ali *et al.* (2012) observed that the milling and cooking qualities were similar in all planting methods (Figure 5).

Economics

Sharma *et al.* (1995a) reported that transplanted and direct seeded rice needed nearly equal investment on cultivation. Transplanted rice required more investment in the beginning, while direct seeded rice needed more expenditure during early to mid crop growth. Puddled rice required more investment in seed bed preparation, nursery raising and transplanting of seedling than direct seeded rice, in which, investment was required for land preparation and sowing, but later needed higher expenditure for weed control (Figure 6). Budhar and Tamilselvan (2001) observed that the direct seeding using drum seeder recorded 14.86% higher net income and 15.72% higher benefit cost ratio than traditional transplanting practice (Table 6). Similar advantages of wet seeding over transplanting were reported by Santhi *et al.* (1998). Sanjay *et al.* (2006) reported that direct seeding (drum seeding) recorded 12.97% higher net income and 14.74% higher returns per rupee investment compared to net income and returns per rupee investment recorded in the line

transplanting system (Table 6). Gangwar *et al.* (2008) revealed that the direct seeded rice vice drum seeding and direct seeding (dry bed) recorded 18.39 and 16.53% higher net return with 17.48 and 7.20% higher benefit: cost ratio than net return and benefit: cost ratio under manual transplanted rice (Table 6). Rashid *et al*. (2009) reported that Direct seeded rice (drum seeding) gave a higher gross margin of Rs 26,137 ha^{-1*} than conventional transplanted rice with gross margin of Rs 24,778 ha^{-1*} (mean of two transplanting treatments).

***According to Average Yearly Exchange Rates of US Dollar to Indian Rupee in 2007**

CONCLUSIONS

It can be concluded that, direct seeded rice is a better option as it save labor, money, time, and energy and gave a similar yield as compared to conventional transplanting methods.

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APPENDICES

Table 1: Effect of Establishment Methods on Growth of Rice

Author	dry Matter Accumulation (q ha^{-1})		LAI (100 Days)		Effective Tillers m^{-2}	
	Direct Seeding	Transplanting	Direct Seeding	Transplanting	Direct Seeding	Transplanting
Gill *et al.* (2006)	141.75	117.31	5.15	4.18	245.9	200.7
Gill and Walia (2013)	153	133	3.4	3.0	256.2	248.2

Table 2: Effect of Establishment Methods on Yield Attributes of Rice

Author	Effective Tillers m^{-2}		No. of Panicles m^{-2}		Panicle Weight (g)		Panicle Lenth (cm)	
	D	T	D	T	D	T	D	T
Miyagawa *et al.* (1998)*			125.5	121.5				
Gill and Walia (2013)*	256.2	248.2	-	-	-	-	26.4	26.2
Bhushan *et al.* (2007)*	-	-	363.5	287	-	-	-	-
Gill *et al.* (2006)*	245.9	200.7	-	-	-	-	23.5	23.6
Sharma *et al.* (2005)*	71.5	72.1	-	-	-	-	27.6	27.8
Singh and Pillai (1996)*	-	-	300	302	2.65	2.82	-	-

No. of Spikelets Panicle^{-1}		Grains Panicle^{-1}		1000 – grain Weight (g)		Yield (q ha^{-1})	
D	T	D	T	D	T	D	T
125.1	143.5			27.55	27.35	31.55	35.85
75.5	71.9	137.2	129.9	21.4	22.0	33.0	32.0
-	-	-	-	28.55	29.95	27.8	29.0
-	-	-	-	22.74	22.64	48.30	42.80
-	-	-	-	-	-	49.0	49.3
-	-	-	-	-	-	42.80	42.30

*means of two years D – Direct seeding, T – Transplanting** Pooled data of four years

Table 3: Effect of Establishment Methods on Yield of Rice

Author	Yield (q ha^{-1})	
	Direct Seeding	Transplanting
Singh and Singh (1993)	26.80	25.50
Narayansamy *et al.* (1993)	52.6	55.6
Gill *et al.* (2006)	48.30	43.80
Gill (2008)	68.2	65.7
Gangwar *et al.* (2008)	82.0	76.5

Table 4: Effect of Establishment Methods on Days Taken to Maturity

Author	Days to 50% Flowering	
	Direct Seeding	Transplanting
Alexander and Martin (1995)	72.3	79.4
Budhar and Tamilselvan (2002)	74.8	82.1
	Days to maturity	
Gill *et al.* (2006)	120	130
Gill (2008)	113	125

Table 5: Effect of Establishment Methods on Water Requirement of Rice of Rice

Author	Irrigation Water (mm)		Water Use Efficiency (Kg ha^{-1} cm^{-1})		water Productivity (kg grain m^{-3})	
	D	T	D	T	D	T
Narayansamy *et al.* (1993)	894	1153	51.8	46.1	-	-
Balasubramanian and Krishnarajan (2000)	1100	1380	49.70	39.2	-	-
Gill (2008)*	1480	1740	-	-	0.461	0.44
Gill *et al.* (2006)*	1100	1233	43.91	3.47	0.44	0.35
Bhushan *et al.* (2007)*	2011	2488.5	-	-	-	-

D – Direct seeding, T – Transplanting, * means of two years

Table 6: Effect of Rice Establishment Methods on Economics of Rice

Author	Net Income			Benefit: Cost Ratio		
	Direct Seeded Rice		Transplanted Rice	Direct Seeded Rice		Transplanted Rice
	Drum Seeding	Dry Direct Seeding		Drum Seeding	Dry Direct Seeding	
Budhar and Tamilselvan (2001)	18587	-	15825	2.29	-	1.93
Sanjay *et al.* (2006)	34953	-	30420	3.12	-	2.65
Gangwar *et al.* (2008)	47040	45990	38390	1.21	1.11	1.03
Rashid *et al.* (2009)	-	-	-	2.5	-	2.5

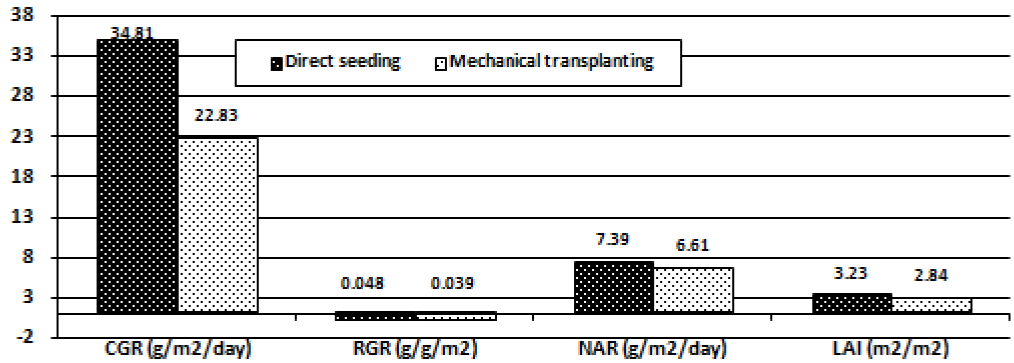

Figure 1: Changes of CGR, RGR, NAR and LAI between Direct Seeding and Mechanical Transplanting Cultivation from Tillering to the Heading Stage

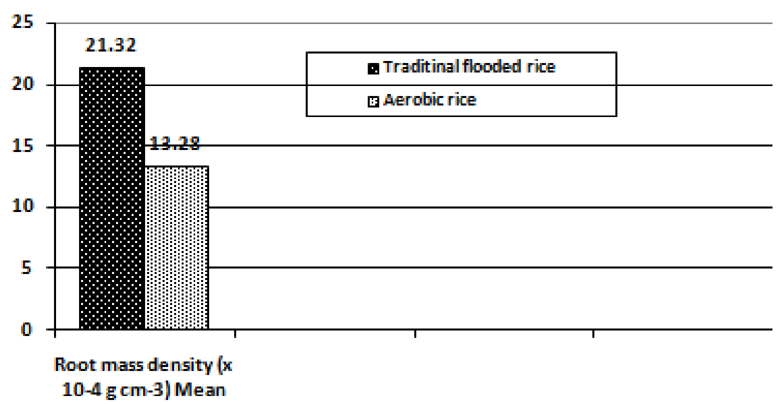

Figure 2: Effect of Establishment Methods on Root Mass Density of Rice

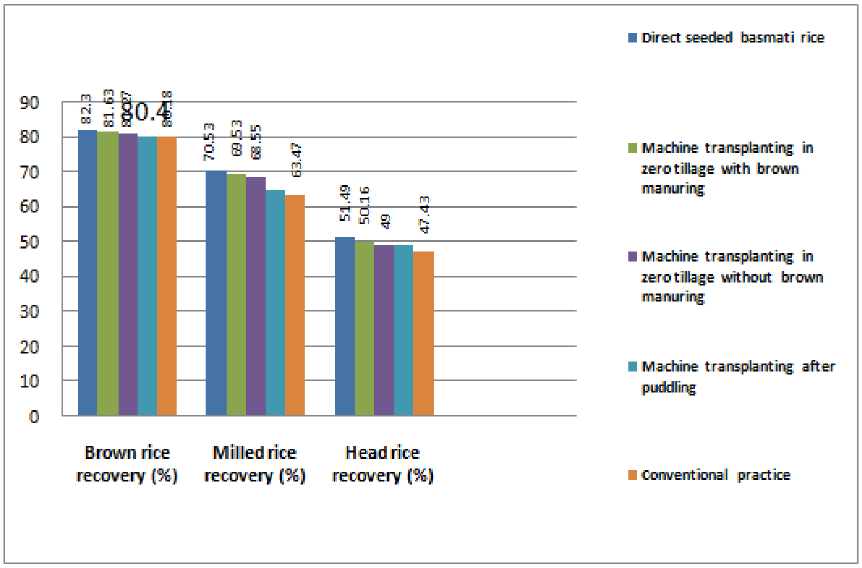

Figure 3: Effect of different Planting Methods on Milling Qualities of Basmati Rice

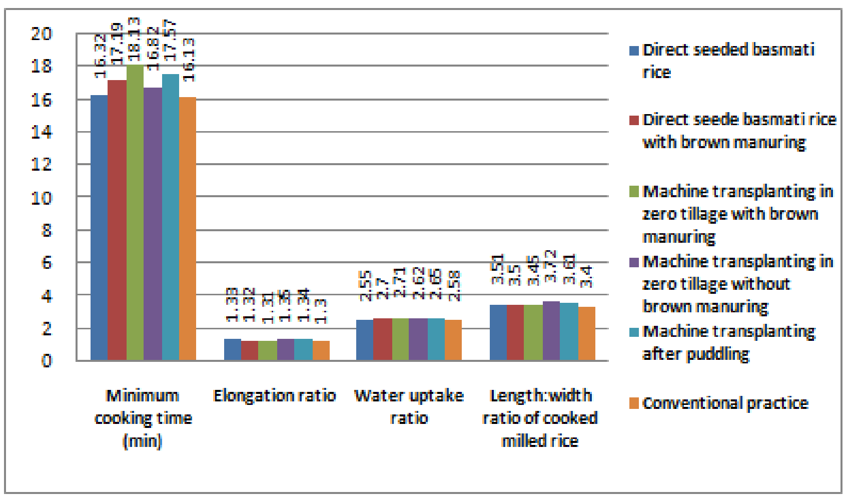

Figure 4: Effect of different Planting Methods on Cooking Qualities of Basmati Rice

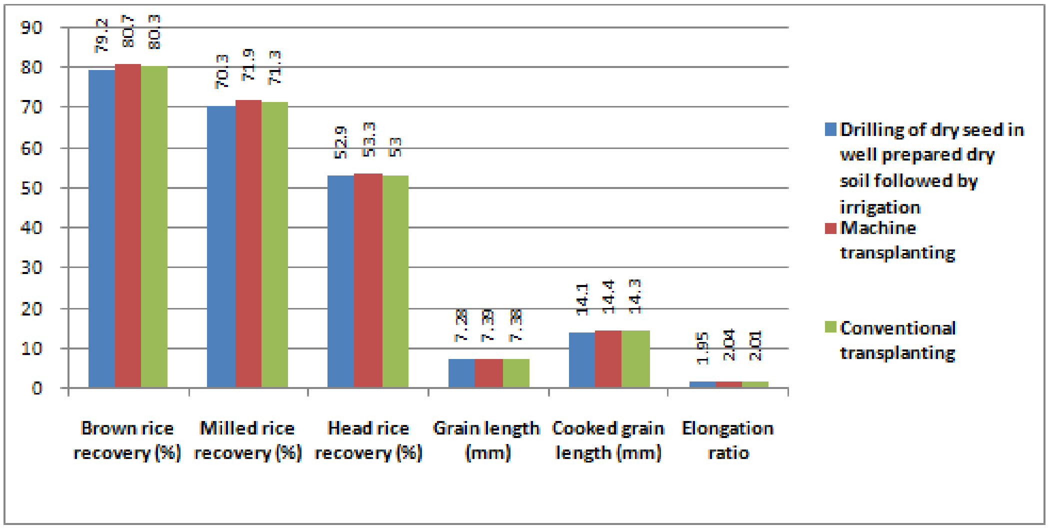

Figure 5: Effect of Different Planting Methods on Milling and Cooking Qualities of Basmati rice

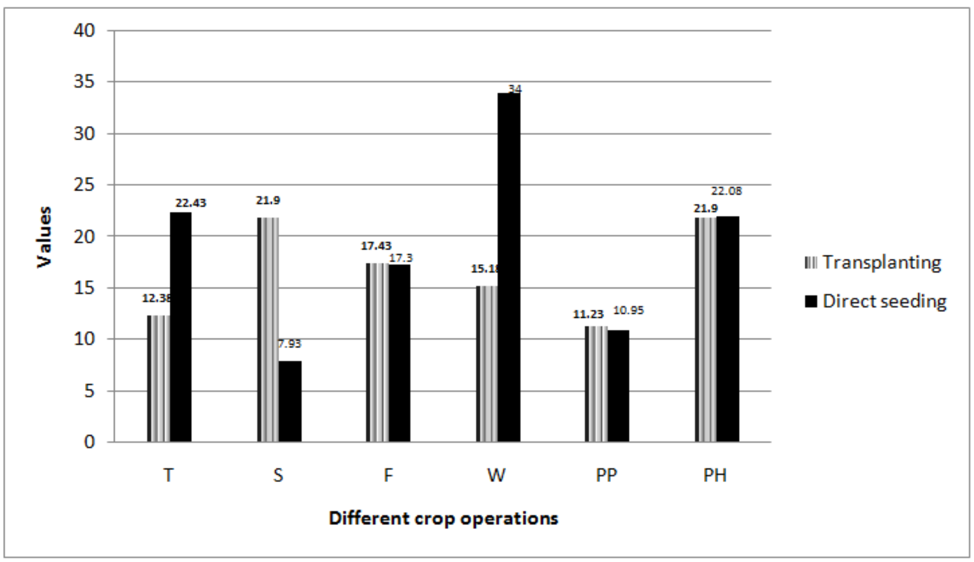

Figure 6: Effect of different Planting Methods on Economics of Basmati Rice

T-Tillage, S-Seeds and Planting, F- Fertilizer Management, W-Weed Control, PP-Plant Protection, PH-Harvesting and Threshing